TOUCH SENSITIVE DISPLAY WITH GRADED INDEX LAYER

[0001] This application claims the benefit of provisional patent application No. 62/221,901, filed Sep. 22, 2015, which is hereby incorporated by reference herein in its entirety.

BACKGROUND

[0002] This relates generally to electronic devices and, more particularly, to electronic devices with touch screen displays.

[0003] Electronic devices often include displays. For example, cellular telephones and portable computers often include displays for presenting information to a user.

[0004] Some conventional displays include a silicon nitride layer that is formed on a glass substrate layer. The index of refraction of silicon nitride is relatively high compared to that of the glass substrate material. For example, silicon nitride may have a refractive index of 1.9, whereas the glass substrate may have a refractive index of 1.5. As a result, there is a significant index-of-refraction mismatch between the silicon nitride layer and the substrate. If care is not taken, the index-of-refraction mismatch may give rise to increased reflection from the display.

[0005] It would therefore be desirable to be able to provide improved touch screen displays for electronic devices.

SUMMARY

[0006] An electronic device that includes display circuitry is provided. In accordance with an embodiment, the display circuitry may include a first display layer having a first index of refraction that is substantially fixed, a second display layer having a second index of refraction that is substantially fixed, wherein the second index of refraction is different from the first index of refraction, and a matching layer interposed between the first and second display layers. In particular, the matching layer may include a first portion having a graded index of refraction that monotonically increases from the first display layer to the second display layer and a second portion having a graded index of refraction that monotonically decreases from the first display layer to the second display layer. The second portion of the matching layer has a thickness that determines what wavelength additional reflection suppression is provided.

[0007] In some arrangements, the matching layer may further include a third portion having a graded index of refraction that monotonically increases from the first display layer to the second display layer. The second portion of the matching layer may be interposed between the first and third portions of the matching layer.

[0008] Incoming light may traverse the first display layer before traversing the second display layer. The first index of refraction may be less than the second index of refraction. The first portion of the matching layer may have a first surface with an index of refraction that matches with the first index of refraction of the first display layer. The first portion of the matching layer may have a second surface with another index of refraction. The second portion of the matching layer may have a surface with an index of refraction that matches the another index of refraction.

[0009] In accordance with another embodiment, an apparatus is provided that includes a first layer having a first index of refraction that is substantially fixed, a second layer having a second index of refraction that is substantially fixed, and a graded index of refraction matching layer interposed between the first and second layers, where the graded index of refraction matching layer includes an embedded reverse matching sublayer.

[0010] In particular, the embedded reverse matching sublayer has an index of refraction that monotonically decreases in a given orientation. The graded index of refraction matching layer may include another sublayer having an index of refraction that monotonically increases in the given orientation (i.e., one sublayer has refractive indices that increase while the other sublayer has refractive indices that decrease).

[0011] The apparatus may also include an additional graded index of refraction matching layer that is interposed between the first and second layers, where the additional graded index of refraction matching layer also includes an embedded reverse matching sublayer. The embedded reverse matching sublayer in the graded index of refraction matching layer may have a first thickness, and the embedded reverse matching sublayer in the additional graded index of refraction matching layer may have a second thickness that is different than the first thickness. Configured in this way, the two matching layers serve to provide enhanced reflection suppression in at least two separate wavelengths.

[0012] Further features of the invention, its nature and various advantages will be more apparent from the accompanying drawings and following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** is a perspective view of an illustrative electronic device such as a laptop computer with a display in accordance with an embodiment.

[0014] FIG. **2** is a perspective view of an illustrative electronic device such as a handheld electronic device with a display in accordance with an embodiment.

[0015] FIG. **3** is a perspective view of an illustrative electronic device such as a tablet computer with a display in accordance with an embodiment.

[0016] FIG. **4** is a perspective view of an illustrative electronic device such as a computer or other device with display structures in accordance with an embodiment.

[0017] FIG. **5** is a cross-sectional side view of an illustrative display in accordance with an embodiment.

[0018] FIG. **6** is a cross-sectional side view of a conventional display stack-up.

[0019] FIG. **7** is a cross-sectional side view of illustrative display layers including a gradual refractive index matching layer in accordance with an embodiment.

[0020] FIG. **8** is a cross-sectional side view of illustrative display layers including a reverse matching layer in accordance with an embodiment.

[0021] FIG. **9** is a diagram showing how the index of refraction may vary within a matching layer of the type shown in FIG. **8** in accordance with an embodiment.

[0022] FIG. **10** is a plot of reflection versus wavelength showing how reflections can be suppressed at a selected wavelength in accordance with an embodiment.

[0023] FIG. **11** is a plot showing how the thickness of the reverse matching layer of FIG. **8** can be varied to adjust the selective reflection suppression wavelength in accordance with an embodiment.